Beyond the APS Detector Pool:

Detector Systems Evaluation & Characterization

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Optics & Detector Group/XSD

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Beamline 2.0 Workshop
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Outline

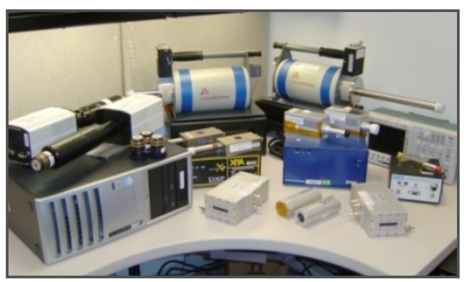
- Overview of APS Detector Pool
- Detector Test Facilities
  - Optics Lab
  - X-ray Tube
  - ODG Beamline (6-BM)
- Examples of Detectors Characterization
- Exploring New Commercial Detectors

Optics & Detectors Group in XSD

- Led by Patricia Fernandez
- Detector Side consists of an R&D and Detector/Equipment Pool section
- Detector Staffing: 4 Engineers, 2 Physicists, 2 Scientific Associates, 2 Technicians
  - + 2 new hires!

APS Detector/Equipment Pool

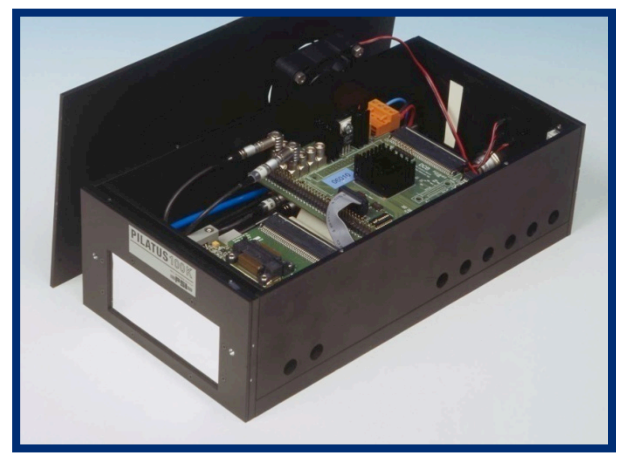
- Provide support for ~ 50 detector systems for temporary loan
  - ~ 300 requests per year.
- We are the outlet for new detectors for the beamlines.
- Centralized source for detector information.
- Characterization of current and new detectors.
  - New Optics and Detectors Beamline
- Detector-driven technique development
  - "Pushing detectors to the limit!"



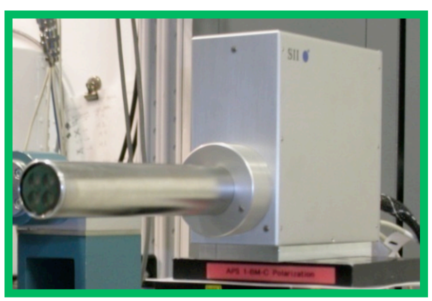
Major Detectors/Equipment

- ***GE & PE Amorphous Silicon Flat Panel (2) (>100%)***
- ***Pilatus 100K Pixel Array Detector (2) (>100%)***
- Mar 345 Image Plate (2) (100%)
- Mar 165 CCD (3) (100%)
  - Frameshift/Kinematics Mode
- Bruker 6500 CCD Detector (1)
- PI CoolSnap & Zeiss/Mitutoyo Optics (2) (75%)
  - Including scintillators
- Other Microscopy CCDs: Sarnoff, Prosilica, etc.
- APS-in-house Avalanche Photodiodes (APDs)
- Ketek Silicon Drift Diode (6)
- SII Vortex Single-element SDD (4) (75%)
- ***SII 4-element Vortex SDD (2) (80%)***
- Single & multi - element Germanium (3)

GE a-Si Flat Panel



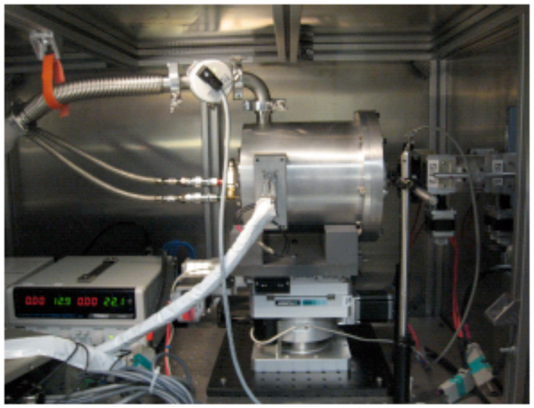
Pilatus 100K

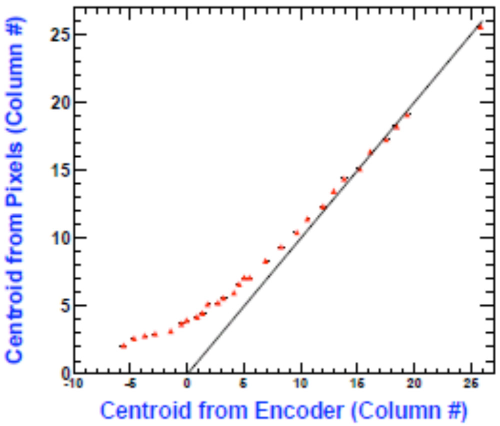


4-element Vortex SDD

X-ray Tube Test Facilities

- **Copper X-ray tube in 401-L0111**
  - Testing of FCCD (John Weizeorick)
  - "Narrow-Beam X-Ray Tests of CCD Edge Response" (submitted 2010)
    - S. Kuhlman et. al. (HEP/ANL)
    - Support by Beyer, Gades, Miceli, and Spence



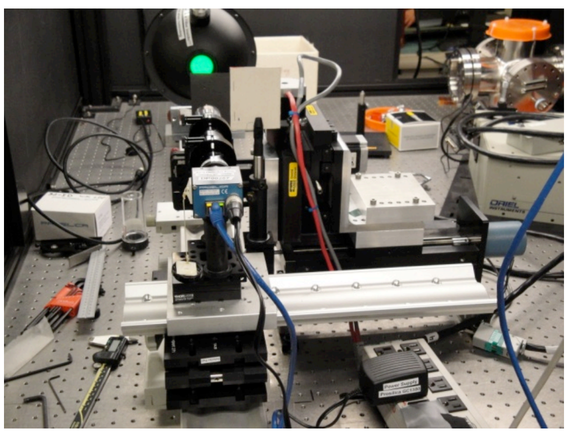


Evidence of E-field distortions at CCD edges!!!

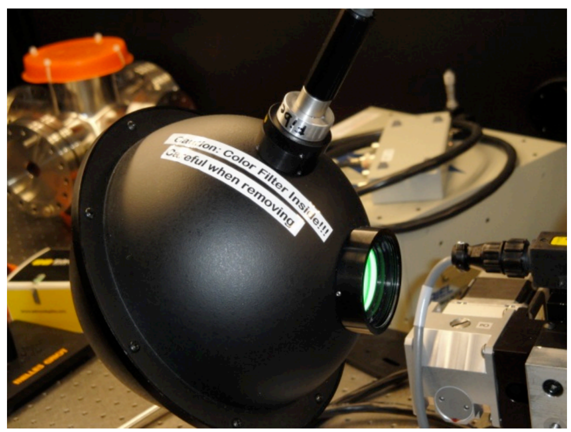
- **Phillips High-Energy X-Ray Tube (W anode)**
  - Currently being commissioned.
  - Flat field Calibration of large area detectors (e.g., GE/PE flat panel)
  - ***Need to develop testing protocols!!***

Optics Test Stand

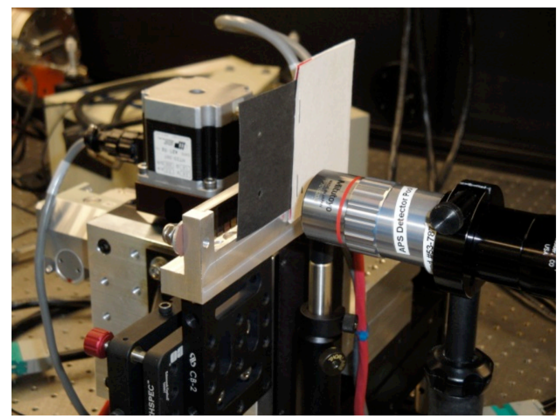
- Visible light testing offline
  - Comparison of microscope optics, tube lens, camera
- The long X95 trail is dedicated to testing optics
- Motors for resolution target (xyz) are controlled by the VME EPICS IOC
- Illumination is controlled by DAC in VME crate
- Detailed analysis of Mitutoyo’s, Infinitube’s, Prosilica’s in progress



Optical Rail



Integrating Sphere with Green Filter



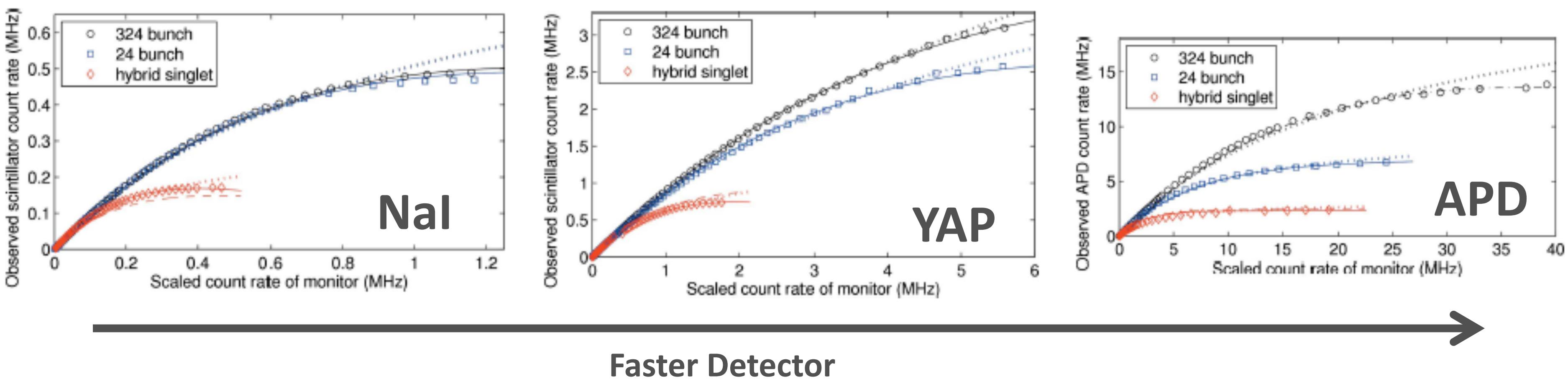
Resolution Test Target

New Optics & Detectors Beamline at APS (6-BM)

- **Will enable systematic and careful detector characterization and re-calibration**
  - For example, energy-dependent threshold re-calibration of Pilatus detectors
  - Flat-fields for various large area detectors (e.g., GE and PE a-Si Detectors)
  - Scintillator testing can only be done at a beamline!!!
- **Will enable testing with synchrotron timing structure**
  - Dead-time corrections with various bunch structures (e.g., hybrid singlet)
    - e.g., Walko et al JSR 2009 & 2010→ Empirical Deadtime corrections of photon counting (point detectors & Pilatus)
- **Will enable detector-driven technique development**
  - Novel uses of detectors.
- ***Need to develop testing protocols!!***

Empirical Dead-time Corrections for Synchrotrons
Walko, Arms & Landahl JSR 2009

- **Should you care if its hybrid single mode??**
- **Yes, if you are using a counting detectors!!!**
  - **Can your detector separate bunches? NaI vs. YAP vs. APD…**

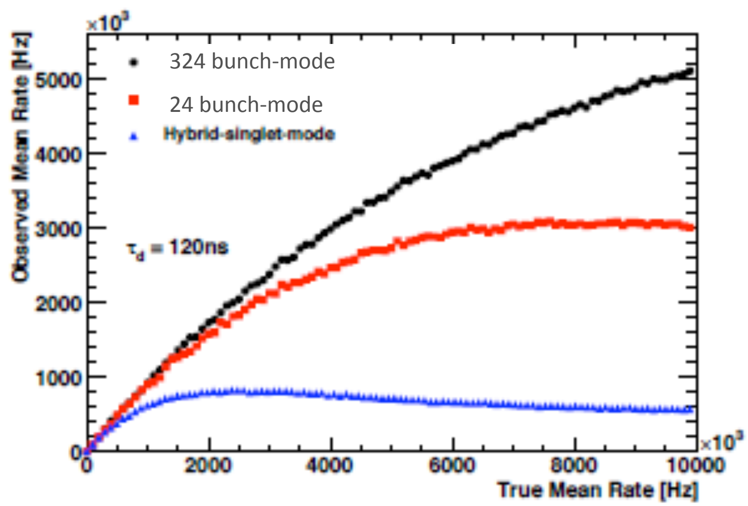


- **Proper dead-time correction depends critically on detector speed and synchrotron fill pattern!!!!**

Dead-time Corrections for Pilatus in APS timing modes…

Modes

- 24-bunches: T = 153 ns
- 324-bunches: T = 11.4 ns
- Hybrid singlet: Single isolated bunch plus eight septets



Monte Carlo Simulations by Dectris

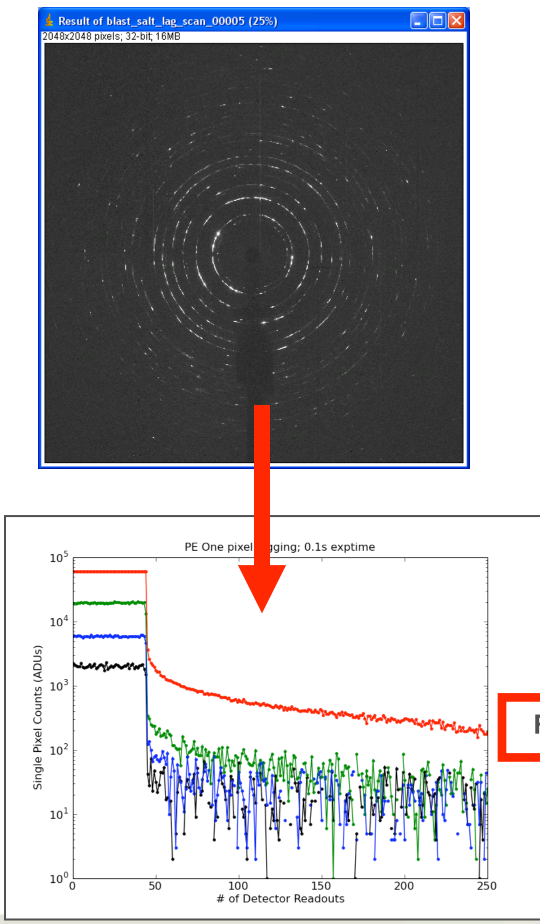
Pilatus deadtime measurements for Pilatus in progress (Walko, Miceli, Kastengren at 7-BM)

Example of Detector Testing & Analysis at 1-ID & 6-ID

(A. Miceli, J. Lee, D. Robinson)

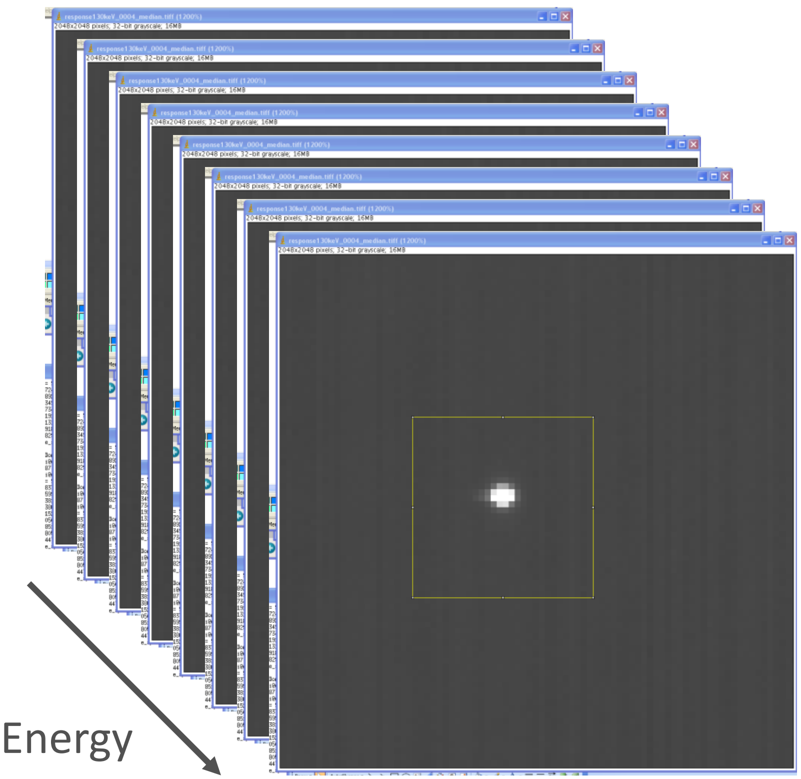
- Comparison of GE & PerkinElmer Flat Panel Detectors

Lagging



Red is Saturated

Broadband energy response (30-130keV)



Energy

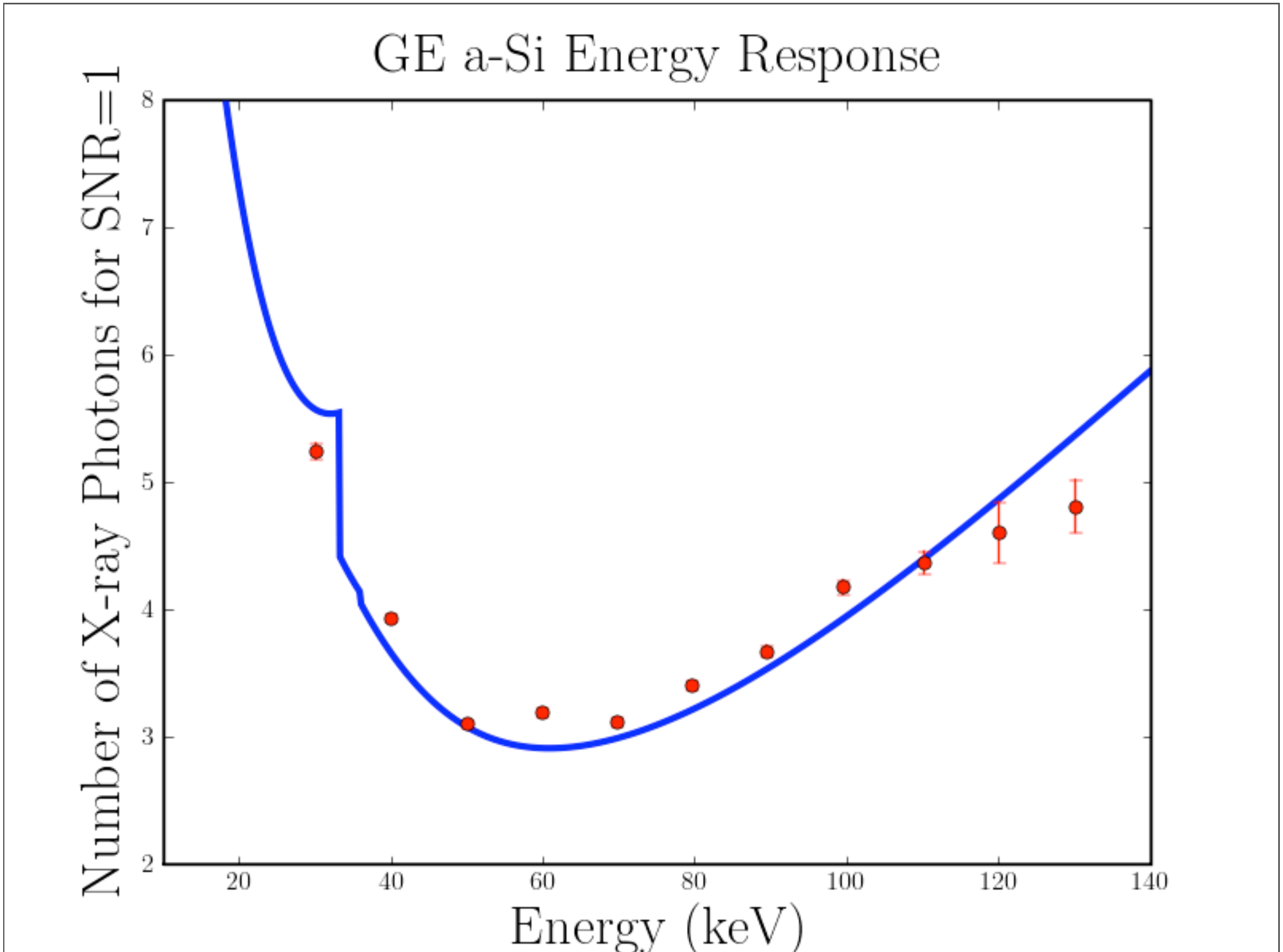
At what energy is a detector most sensitivity??

Simple Energy-Dependence Model for Indirect Detection Area Detectors

$$f(E, e_{scintillator}) = \underbrace{((E \times 1000) / 2.18\text{eV})}_{\text{light yield}} \times \varepsilon_{scintillator} \times \underbrace{\mu_{CsI}}_{\text{x-ray absorption probability in CsI}}(E)$$

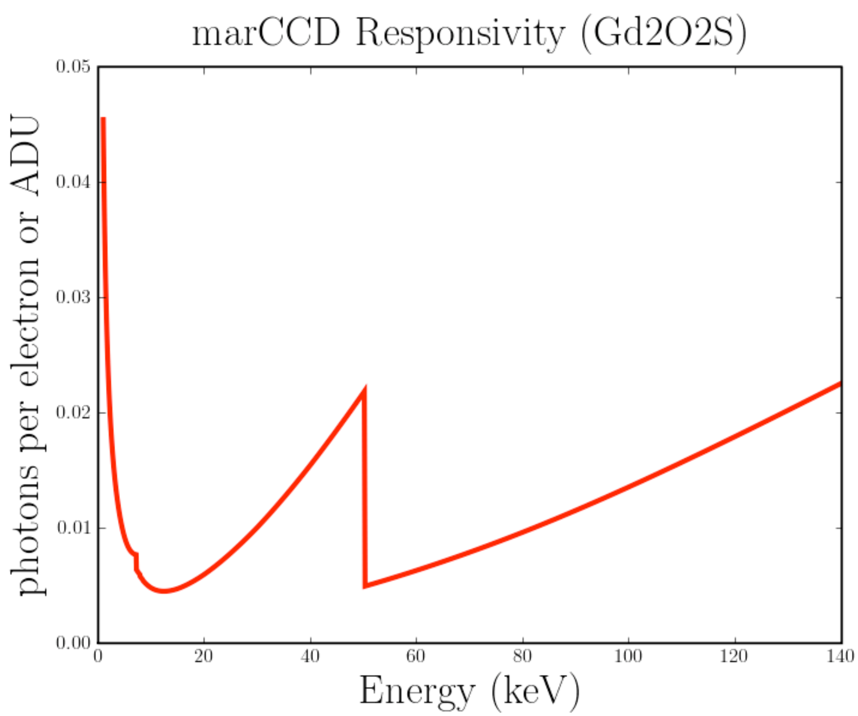
1. CsI(Tl) emits at 570 nm (2.18eV) (i.e., light yield)
2. $\varepsilon_{scintillator}$ composed of:
   - Fraction of absorbed energy transferred to optical photons
   - Fraction of optical photons that actually get to photodiode
     - Might be energy dependent.... How deep does x-ray interact in CsI?
   - Optical photon to electron conversion (QE of photon diodes)
   - Electron to ADU gain (4400 electrons/ADU)
   - Main assumption: $\varepsilon_{scintillator}$ is independent of energy!!!!!!!
     - Might be ok assumption, though......

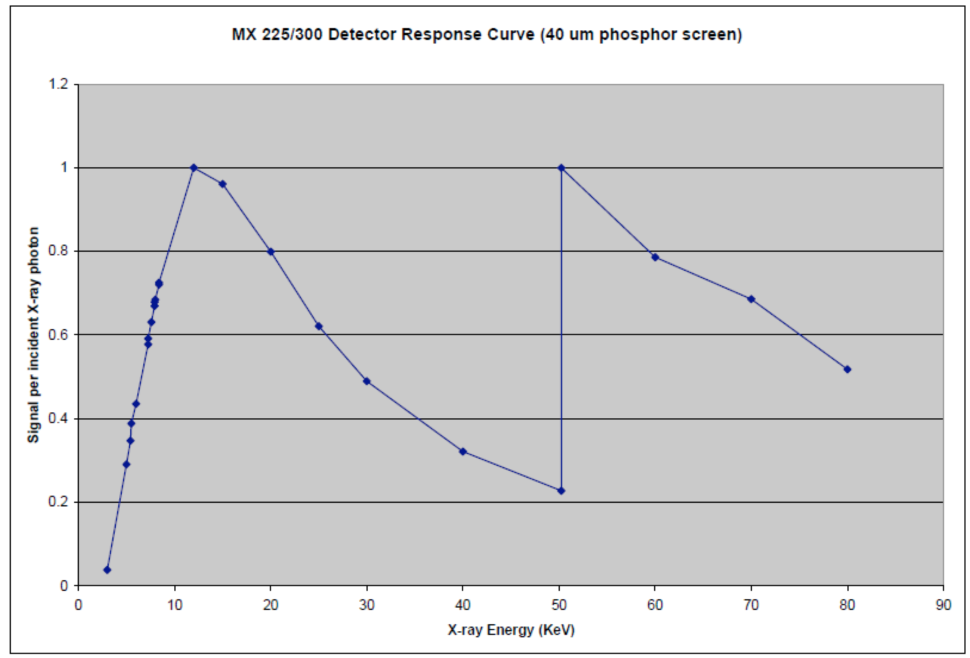
Energy-dependence Response of GE a-Si Flat Panel



Miceli & Lee

Energy Response of marCCD





Data Corrections: *Energy of the Compton scattering is Q-dependent* (e.g., PDF measurements) (Chupas et al)

Exploring New Commercial Detectors

- There are many commercial detectors that could be useful for the APS.
  - Need to explore, evaluate, and test these detectors at the APS!
    - a-Se detectors from medical mammography (e.g., ANRAD, Hologic)
    - CMOS flat detectors (Hamamatsu, etc)
    - High-energy/high-resolution detectors from the dental imaging market.

- Working with other labs (e.g., Peter Siddons with Maia detector?) and companies to adept/modify detectors for the APS.
  - Not detector research!
  - Semi-commercial detectors.
  - “Detector Systems Engineering”
    - Custom packaging, readout electronics, software
  - Find companies to collaborate with via SBIRs.

This is a full time job!!!

Conclusions

- APS Detector Pool overview
- Careful and detailed detector characterization
- Bring more non-tradition commercial detector to APS.
  - Evaluate performance & characterization protocol.
  - Integrate into the beamline with software (See Mark's Talk)
- Better name for the Detector Pool?
  - "APS Detector Systems"